PATENT SPECIFICATION

1,072,578

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Int. Cl.:—F 16 h // B 21 b, B 23 g.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Screw Thread System

We, STANDARD PRESSED STEEL CO., of Jenkintown, Pennsylvania, United States of America, a corporation formed and existing in accordance with the Laws of the Commonwealth of Pennsylvania, one of the States of the United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method for increasing the fatigue life of a loaded screw thread system including internally and externally threaded co-operating members and to a new screw thread form or configuration which will increase the fatigue life of the externally threaded element under load by redistributing the stress concentrations within the thread itself or by more equally distributing the loading stresses throughout the length of thread engagement. Another aspect of this invention is directed to the tool or die for forming threads having the aforesaid configuration.

The fatigue life of the externally threaded member of a screw thread system can be increased by modifying the basic or fundamental thread form in such a way that the threads—particularly the threads which carry the greatest load—are rendered more flexible and therefore capable of being deflected (hereinafter where the term deflected is used it will be understood that it is also intended to refer to deformation of the thread) under lower loads than will deflect the basic thread form; and without simultaneously inducing bending stresses in the deflected threads which are of the same general order or greater than the loading stresses which are shifted from the deflected threads.

According to the present invention in a screw thread system the pressure flank of the internal thread from its root at least to the vicinity of its pitch line is disengaged from the pressure flank of the external thread, and the internal thread has, when in an unloaded condition, a progressively longer lead than the lead of the unloaded external thread, and the true pitch diameter of the internal, or the external thread, or both, are changed to prevent an interference fit when in an unloaded condition.

The lead differential will, in general, be sufficient to compensate for the shortening of the lead of the internal thread and the elongation of the external thread which occurs on loading and thereby will provide for a more uniform distribution of stress concentration at the roots of the engaged external thread. The change in the true pitch diameter will cause the virtual pitch diameter to approach the basic pitch diameter. The pressure flank of the internal thread is preferably in contact with the pressure flank of the external thread in the vicinity of the pitch line when the system is loaded.

The thread form modifications may be used in conjunction with lead corrections of the type disclosed in British Patent No. 1.032.814. In that Patent, Claim 1 reads:—

A screw-threaded fastener including a nut having a constant major internal diameter and a bolt having constant major and minor diameters, said nut being axially counter-bored to truncate the crests of from one to four nut threads adjacent the bearing face of the nut, said counterbore extending radially substantially no further than the pitch diameter of the nut, and said fastener being characterised in that the internal threads, when in an unloaded condition, have a progressively longer lead from the bearing face than the lead of the unloaded external

threads, the lead differential being sufficient to compensate for the shortening of the lead of the internal threads and the elongation of the lead of the external threads which occurs on loading of the fastener and thereby provide for a more uniform distribution of the stress concentrations at the roots of the engaged external threads, the true pitch diameters of the internal and external threads being corrected to cause the virtual pitch diameters to approach the basic pitch diameters and thereby prevent an interference fit when in an unloaded condition.

As used herein, the term "thread system" is intended to refer to all types of combinations of internal and external screw thread arrangements which employ ridges of uniform section in the form of a helix on the external and internal surfaces of a cylinder or frustum of a cone. However, embodiments of the invention will be described by way of example with reference to thread systems in the form of nuts and bolts and particularly, in terms of single start straight threads having a basic or fundamental 60° thread form.

The accompanying drawings illustrate several embodiments of thread form configuration which will serve to effect one or more of the modifications that are useful either alone or in combination with lead correction, for increasing the fatigue life of the thread system under load.

Figure 1 is a view in section of a modification which will be referred to as the "involute" thread form.

Figures 2 and 3 are sectional views of modified thread forms which will be referred to as "semi-involute" thread forms.

Fig. 4 is a sectional view of a modified thread form in which, inter alia, the moment arm acting on the internal threads is increased.

Fig. 5 illustrates a Waterbury die for forming the flanks, roots and crests of involute external threads by rolling.

Fig. 6 illustrates a Waterbury die for forming the flanks, roots and crests of asymetrical semi-involute external threads by rolling.

Fig. 7 illustrates one die of a set of Reed dies for the rolling of external threads.

Fig. 8 illustrates a tap for forming internal threads.

Fig. 19 is an enlarged sectional view showing the lead differential correction of the type disclosed and claimed in the said Patent and which, in accordance with the invention, serves, in combination with the various high fatigue thread configurations described above, to increase the fatigue life of the system to a greater degree than is obtained with form modification alone or lead correction alone.

In Fig. 1 there is illustrated an external thread 10, and an internal thread 11; the basic or fundamental thread form for both the internal and external threads are shown in dotted lines. The line of the pitch cylinder is the dot-dash line P-P'. The pressure flanks of the thread are 12 and 12', the clearance flanks of the thread are 13 and 13'.

From a point 14 on the pressure flank which in the illustrated embodiment is in the general vicinity of the pitch line P-P' the flank of the external thread diverges away from the side 15-16 of the fundamental thread triangle 15-16-17 and forms a curved flank surface which, under load, will bear tangentially against the pressure flank 12' of the associated conventionally formed internal thread. In this embodiment, the point of tangency 14 is positioned in the vicinity of the line of the pitch cylinder P-P', however, the point of tangency 14 can be either above or below line P-P' and still provide the benefits of the invention. The root of the external threads preferably are radiused at 20 but other root configurations which do not contact or create interference with the crest 21 of the internal thread or the flank portions 22 extending from the crest 21 toward the pitch line on the pressure flank can be used. The clearance flank 13 has a corresponding configuration, hence, this type of thread form is sometimes referred to as the symmetrical involute thread. It will be observed that the involute thread form embodiment of Fig. 1 effects two types of modification or corrections:—

(a) it locally disengages the threads in the vicinity of the pressure flanks where they join the root radius of the external threads thus eliminating the application of additional stresses in an otherwise highly stressed area.

(b) the section modulus of the external thread 10 is decreased from that of the basic thread form 15-16-17 thereby rendering the external thread more flexible. Both correction cooperate to increase the fatigue life of the loaded thread system as previously described.

Where the point of tangency 14 is either above or below line P-P', the corrections will also serve to increase the moment arm. If the point of tangency is above P-P' at 14' the moment arm on the external thread will be increased and the moment arm of the internal thread decreased. If the point of tangency is below P-P' at 14" the moment arm of the internal thread will be increased and that of the external thread decreased.

It is also possible to provide thread modifications according to this invention where the involute configuration is given only to the pressure flank and the clearance flank is uncorrected. Such thread forms are referred to as asymmetrical involute threads.

In the thread form illustrated in Fig. 1.

radius 19 is equal to four times the thread height 27 and extends between the point of tangency 14 and the external thread crest 24 and the radius 18 is equal to one-half the thread height 27 and extends from the point of tangency 14 toward the root 25. The root radius 20 is swung from a point 20′ midway between the flanks at 75% of the thread height. These radii have been found to give outstanding performance where the point of tangency is in the general vicinity of the line of the pitch cylinder but the invention is not to be deemed as limited thereto.

Figs. 2 and 3 illustrate two embodiments of semi-involute external thread forms. Fig. 2 is an asymmetrical external thread with an involute pressure flank extending toward the crest and in Fig. 3 an asymmetrical external thread form is shown in which the pressure flank diverges from contact on a straight line extending toward the crest.

Referring to Fig. 2, there is illustrated an external thread 30 and an internal thread 31. The portion of the pressure flank 32 from the line of the pitch cylinder P-P′ to the crest 33 of the external thread is formed in the same manner as the involute embodiment of Fig. 1: the radius 34 extending between the pitch line and the crest is tangent to the fundamental thread triangle in the general vicinity of the pitch line P-P′. The point of tangency 34′ can, however, be above or below the pitch line, e.g., at 35 or 36. Below the point of tangency, the thread has a conventional configuration. In the preferred embodiment, the flanks, roots and crests of the external thread are formed by one step thread rolling operation. In this connection, machining the correction onto a conventional thread form will induce surface stresses and necessitate a retempering operation to remove these stresses. Further rolling permits a greater freedom of formation and enables higher strength (e.g., up to 260,000 p.s.i.) materials to be threaded.

Further, because the asymmetrical semi-involute thread form has greater mass above the pitch line than does the symmetrical semi-involute thread, the asymmetrical form will, under certain circumstances, have greater resistance to shear and will therefore be less subject to stripping. In addition, the asymmetrical embodiments of external semi-involute thread will, when used with a nut having a prevailing torque lock provided by displaced or non-circular thread configurations, exhibit more efficient locking action than the corresponding symmetrical semi-involute embodiment.

The asymmetrical semi-involute thread form of Fig. 2 serves to increase the fatigue life by increasing the moment arm acting on the internal threads and shortening the moment arm of the external threads. The internal threads will, therefore, deflect more under load and thereby more uniformly redistribute the load. The external thread will be more rigid and less likely to have objectionable bending stresses set up which will offset the gains obtained by load redistribution.

The embodiment illustrated in Fig. 3 is also an asymmetrical semi-involute external thread form. There is illustrated an external thread form 40 and an internal thread 41 of standard configuration. The pressure flanks are 42 and 42′ and the clearance flanks are 43 and 43′. On the pressure flank 42 of the external thread at a point 44 at a uniform height relative to the line P-P′ of the pitch cylinder, the flank 45 diverges away from the side of the fundamental thread triangle shown in dotted lines and joins the crest 46. The flank angle α_1 of the first portion 47 of the pressure flank running from root toward crest is the same as the flank angle α of the basic thread triangle and of the clearance flank but it is less than the flank angle α_2 of the second portion 48 of the pressure flank running from crest toward the root. For the same reasons expressed above in connection with the Fig. 2 embodiment, it is preferred to form the roots, crests and flanks of this thread configuration by rolling. In this embodiment, the point of divergency 44 is below the line of the pitch cylinder P-P′ — about midway between the root of the external thread and the pitch line thereby making the internal thread more flexible and the external thread more rigid.

The benefits and advantages obtained by the Fig. 3 embodiment are the same as those explained in connection with the configuration of Fig. 2.

Fig. 4 illustrates an embodiment wherein the internal thread has a conventional configuration and flank angle α; the external thread 60 has been modified so that its flank angle α_2 is greater than α: thus where α is 30°, α_1 should be about 32 to 35°.

According to a preferred feature of the invention, the thread form modification need only to be applied to the pressure flanks of those external or internal threads which are nearest to the nut or other bearing face and which, therefore, carry the greatest load. In general, the benefits of this invention will be obtained if the correction is applied to the first engaged full thread at the bearing face and some further benefits are obtained if the correction is applied to from 2 to 5 of the engaged threads immediately adjacent the bearing face.

By further modifying the thread forms heretofore described in the manner set forth in the aforementioned Patent No. 1032814, still greater improvement in fatigue life will be obtained. Thus, for example, a 1/2 - 20 external wrenching bolt heat treated to pro-

vide a 220,000 p.s.i. minimum strength level and having the involute thread form of Fig. 1 when used in combination with standard internal threads has been found to increase the fatigue life of the loaded thread system (over that of a thread of conventional configuration) by about 350%; and if this involute external bolt is used in a system also having a positive lead correction (as described in Patent No. 1,032,814 of 0.006 inch per inch of thread engagement between the nut and bolt, the fatigue life will be about 700% greater than that of thread system having a conventional thread form and matching leads.

As disclosed in the above Patent Specification, when the cross sectional areas of the internal and external threads are substantially equal the optimum lead correction can be determined from the following formula:—

$$Le = \frac{2(n-1)F_t}{nAE}$$

wherein: Le = inches of lead differential between nut and bolt per inch of thread engagement; n = number of engaged threads; F_t = total tensile load in pounds; E = the modulus of elasticity of the nut in pounds per square inch; and A is the cross sectional area.

In addition, the lead differential should not be sufficiently large as to cause the unloaded system to have an interference fit. If the lead correction is so large as to cause an interference fit, it is necessary to also change the true pitch diameter of the lead corrected threads to compensate for the change in virtual pitch diameter which results from lead differential. The change in true pitch diameter (ΔPD) for 60° basic thread forms can be computed from the following formula:—

$$\Delta PD = 1.732 \times Le \times H_t$$

wherein H_t = nut height in inches. The ΔPD correction will be (+) for internal threads and (−) for external threads, and can be applied to either or both members of the fastener combination.

Fig. 9 illustrates schematically the lead corrected thread system according to Patent No. 1032814.

In Fig. 9—

P = 1/no where no is the number of threads per inch

ΔP_B = change in pitch length of the bolt in inches

ΔP_N = change in pitch length of the nut in inches

PD_B = basic pitch diameter of the bolt in inches assuming perfect thread form and configuration; and where Le = 0 it will be both the true and the virtual pitch diameter.

PD_N = true pitch diameter of the nut in inches assuming perfect thread form and configuration; and where Le = 0 it will be virtual pitch diameter.

S_N = Stress on nut

S_B = Stress on bolt.

Another aspect of this invention is concerned with tools and dies for forming threads of the type disclosed herein.

Figs. 5 and 6 each illustrate one die of a set of Waterbury dies which can be used to roll form the roots, flanks, and crests of external threads having high fatigue characteristics. The die of Fig. 5 can be used to form threads of the type illustrated in Fig. 1. As shown in Fig. 5, the die is provided with a series of parallel ribs 50 whose cross section as can be seen in the enlargement (Fig. 5′) is a true mating configuration for the symmetrical involute die of Fig. 1. The rib flanks 51 for forming the pressure flanks of the screw threads are defined in cross section by two curved portions 52, 53—usually on differing radii—curved portion 52 extending from the rib crest toward the rib root and curved portion 53 extending from the rib root toward the rib crest. Portions 52 and 53 converge at a reference line 54 extending along the rib flank at a uniform height relative to the rib root. The curved portions 52 and 53 are tangent to the fundamental rib triangle shown in dotted lines at the reference line 54 and diverge away from the side of the fundamental rib triangle as they curve from the reference line toward the rib root and the rib crest. The reference line 54 can be positioned at above or below the line of the pitch cylinder of the screw thread to be formed with the die. In Fig. 5, the reference line 54 is at the pitch line P-P′.

The die of Fig. 6 can be used to form semi-involute asymmetrical threads akin to the external thread of Fig. 3. The die includes a series of parallel ribs 61 whose cross section can be seen in the enlargement Fig. 6′. The rib flanks 61 for forming the pressure flanks of the screw thread include two angularly arranged portions 62, 63, which intersect at a reference line 64 extending along the rib flank at a uniform height relative to the rib root. The flank angle α of rib portion 62 between the rib crest and the reference line is less than the flank angle α_1 of the rib portion 63 between the rib root and the reference line and the flank angle α_2 of the clearance flank forming rib 65, from root to crest, is equal to α. The reference line 64 can be at above or below line of the pitch cylinder P-P′ of the screw thread to be formed therewith.

Fig. 7 depicts one die of a set of Reed dies for rolling external threads and Fig. 8 is a tap for forming internal threads, both instrumentalities can be used to impart configurations of the type described in this application if the helex rib is given an appropriate mating cross section.

The top or die will also be arranged to give the features of Figure 9.

As used herein, the term "basic thread form" is the theoretical profile of the thread for the length of one pitch in an axial plane, on which the design forms of the threads for both the external and internal threads are based. The term "fundamental triangle" is the triangle whose corners coincide with three consecutive intersections of the extended flanks of the basic form.

WHAT WE CLAIM IS:—

1. A screw thread system including internally and externally threaded co-operating members in which the pressure flank of the internal thread from its root at least to the vicinity of its pitch line is disengaged from the pressure flank of the external thread and in which the internal thread has, when in an unloaded condition, a progressively longer lead than the lead of the unloaded external thread, and in which the true pitch diameter of the internal or the external thread, or both, are changed to prevent an interference fit when in an unloaded condition.

2. A screw thread system according to Claim 1 including a nut and having a 60° basic thread form, wherein the change in the true pitch diameter ΔPD. is in accordance with the following formula—

$$\Delta PD = 1.732 \times Le \times H_t$$

wherein Le is the lead differential in inches per inch of thread engagement, and Ht is the nut height in inches.

3. A screw thread system according to Claim 1 or Claim 2 wherein the flank angle of the pressure flank of the internal thread is 30° and the flank angle of the pressure flank of the external thread is between 32° and 35°.

4. A screw thread system according to any preceding claim in which the pressure flank of the internal thread is in contact with the pressure flank of the external thread in the vicinity of the pitch line.

5. A screw thread system according to any preceding claim wherein the pressure flank and the clearance flank of the external thread together form a symmetrical cross section.

6. A screw thread system according to any of Claims 1 to 4 wherein the pressure flank and the clearance flank of the external thread together form an asymmetrical cross section.

7. A screw thread system according to any preceding claim wherein the flanks, crests and roots of the external thread have been formed by rolling.

8. A screw thread system as claimed in any preceding claim in which the pressure flank of the external thread when the system is loaded is locally disengaged from the pressure flank of the internal thread in the vicinity of the junction of the external thread's root radius and the pressure flank of the external thread.

9. A schrew thread system substantially as herein specifically described with reference to any of Figures 1-4 of the accompanying drawings.

10. A tap or a set of taps and die or a set of dies arranged to form members of a screw thread system as claimed in any preceding claim.

KILBURN & STRODE,
Chartered Patent Agents,
Agents for the Applicants.

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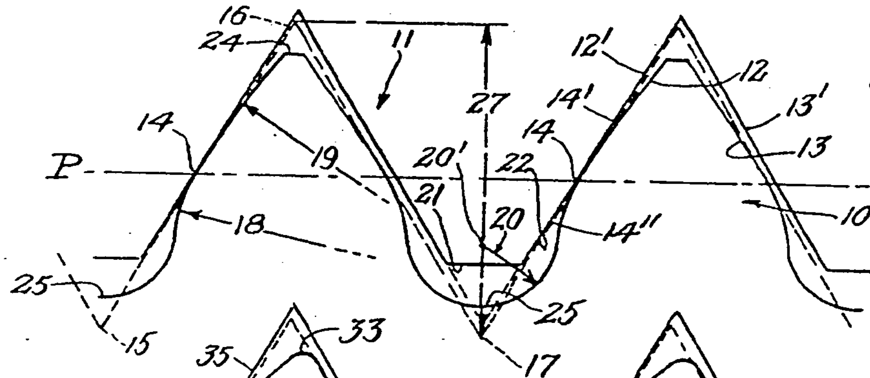

Fig. 1.

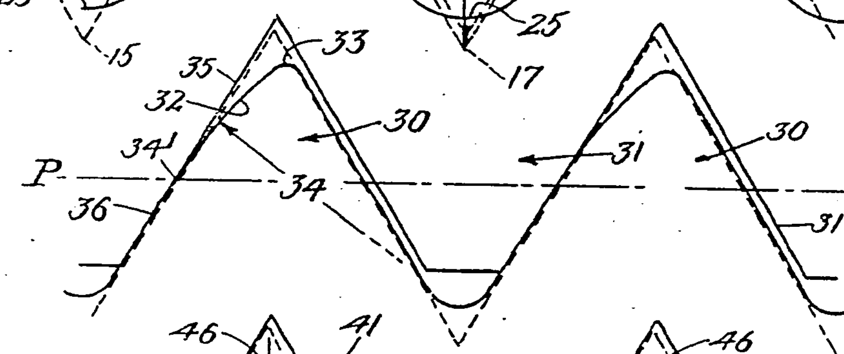

Fig. 2

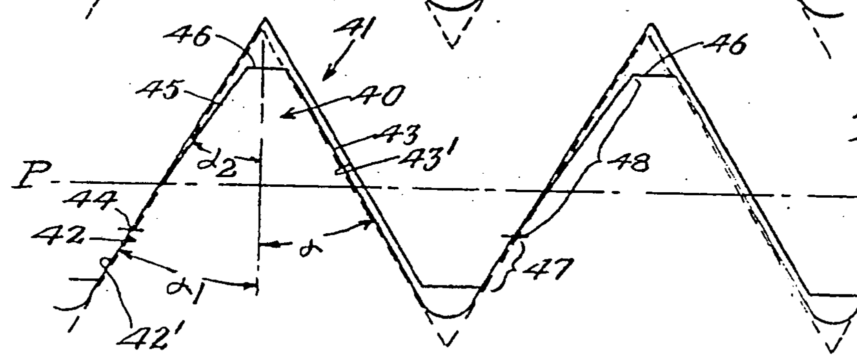

Fig. 3.

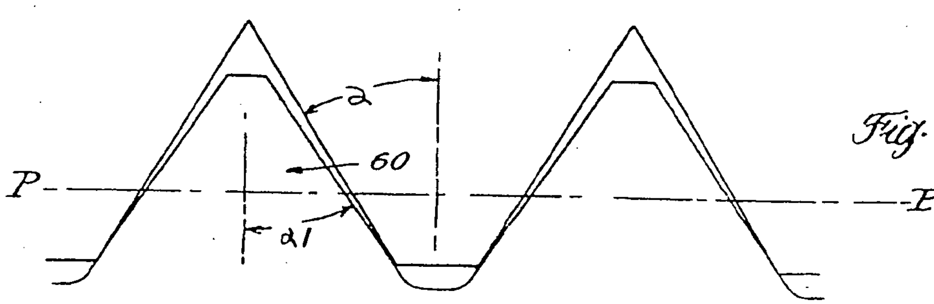

Fig. 4.

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1,072,578 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale.*
SHEETS 1 & 2

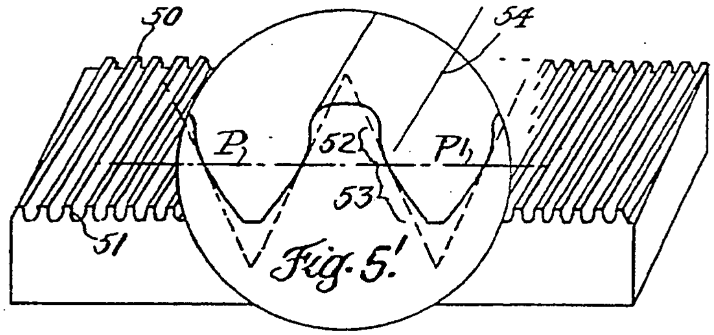


Fig. 5.

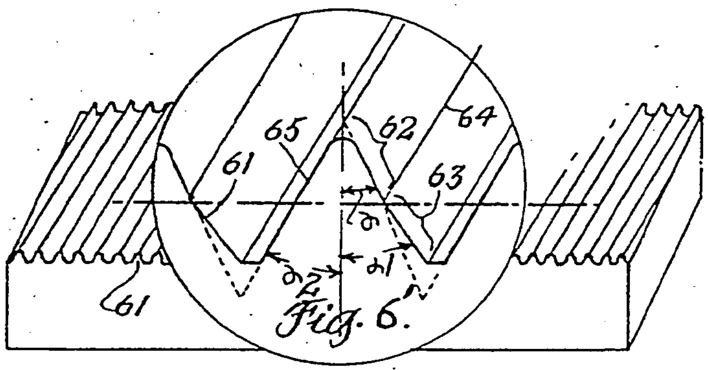


Fig. 6.

Fig. 7.

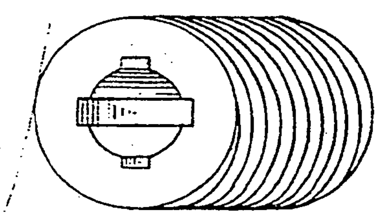
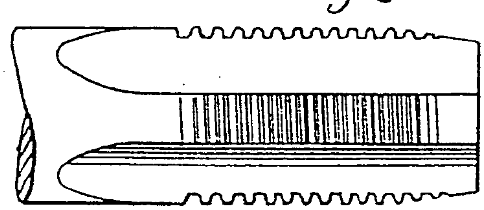


Fig. 8.



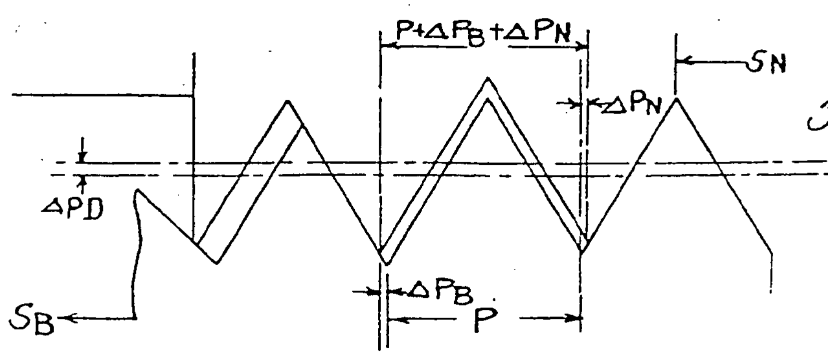


Fig. 9